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# NOTES ON WATER WASTE PREVENTION WORK IN NEW YORK CITY.

BY

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# NOTES ON WATER WASTE PREVENTION WORK IN NEW YORK CITY.

BY WILLIAM W. BRUSH, DEPUTY CHIEF ENGINEER, BUREAU OF WATER SUPPLY, DEPARTMENT WATER SUPPLY, GAS AND ELECTRICITY, NEW YORK CITY.

[*Read September 10, 1913.*]

Conservation of resources and elimination of waste are to-day receiving preferential attention by both municipal and private corporations, and in the past three years New York City has accomplished results along these lines in her water-supply system, unequaled, it is believed, by any other municipality. In 1910 New York had a per capita consumption of 111 gallons, which was lower than that of seven out of the first ten American cities, as shown by the following table:

| City. | Estimated Population, 1912. | Daily Water Consumption per Capita. 1912. | Daily Water Consumption per Capita. 1910.* |
|---|---|---|---|
| New York | 5 053 000 | 100 | 111 |
| Chicago | 2 350 000 | 199 | 235 |
| Philadelphia | 1 600 000 | 200 | 203 |
| St. Louis | 710 000 | 118 | 109 |
| Boston | 718 900 | 125 | 130 |
| Cleveland | 660 000 | 111 | 102 |
| Baltimore | 569 000 | 128 | 115 |
| Pittsburg | 517 000 | 236 | 197 |
| Detroit | 566 000 | 185 | 177 |
| Buffalo | 450 000 | 310 | 321 |

Even with this comparatively low consumption, during less than three years water-waste work, New York has reduced her total consumption from 525 m.g.d. to 486 m.g.d. If allowance be made for the normal three per cent. yearly growth in population, this reduction is equivalent to 90 m.g.d., or more water than the present supply of St. Louis or Boston, with their population of nearly three quarters of a million.

As this reduction has come from a net expenditure of about one hundred thousand dollars and a gross expenditure of less than one hundred and fifty thousand dollars, the efficiency of the methods

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* The figures given are, as far as possible, for the year 1910.

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used cannot be questioned, and an outline of the work should be interesting to water-works officials.

## Boroughs of Manhattan and The Bronx.

### REASONS FOR UNDERTAKING WATER WASTE PREVENTION WORK.

The Boroughs of Manhattan and The Bronx obtain their supply from the watersheds of the Croton, Bronx, and Byram rivers. The continuity of the supply is absolutely dependent upon stored waters, as the run-off of the rivers is, at times, less than the evaporation.

In the spring of 1910, all the available reservoirs in the Croton Valley were full, and water wasted over the New Croton dam up to May 17, when there were 88 690 million gallons, stored in the nine reservoirs and six ponds which are available to hold the water from the 360 square miles that constitute the Croton shed. In the Bronx and Byram shed, covering 22 square miles, there are four reservoirs and ponds, holding 4 195 million gallons, and these were also full. The unprecedented dry season, commencing about July 1, 1910, resulted in a depletion of the stored water in the Croton basins, amounting to 50 583 million gallons by February 28, 1911, when the storage was only 38 107 million gallons. At this time there was little or no snow on the ground and no reasonable hope of heavy spring run-off to replenish the depleted storage.

The consumption at this time was running over 330 m.g.d., and the recorded flow for the Croton River from the year 1868 to 1910 showed that if this rate of consumption continued, and the run-off was no lower than that previously recorded, all the reservoirs would be empty by September. This would mean that there would be practically no water available for a community of three million people, as the flow of the river after a dry summer would be only a small fraction of the normal consumption from the Croton system.

The paralyzing of the industries of the greatest manufacturing city in America, the suffering of the people, and the danger to property and health that would result from a stoppage of the water supply even for a few days' time, constituted a menace to the welfare of the city so great that the Commissioner of Water

Supply, Gas and Electricity, Hon. Henry S. Thompson, immediately commenced, through the public press, to inform the citizens of the condition of the water supply and the need for conserving it. This publicity campaign was productive of results as shown by a reduction in consumption in the month of May amounting to 26 million gallons daily, as compared with the same month of 1910, allowing three per cent. for the normal yearly increase in population and consumption. As the dry weather continued, more radical measures were deemed necessary, and in May it was recommended that the following steps be taken:

### RECOMMENDATIONS TO CONSERVE WATER SUPPLY.

1st. Printed notices be delivered at every building in Manhattan and The Bronx, stating the need for stopping waste and calling attention to the fine which the commissioner might impose if the waste was not stopped.

2d. House-to-house inspection to be made by a special corps.

3d. Pitometer work to be undertaken along the river-front, to detect leaks in mains or services.

4th. Surveys to be made and plans drawn for a temporary source of supply of about 50 million gallons daily capacity.

These recommendations were approved and the following notice was printed in English, Italian and Yiddish:

### PRINTED NOTICE TO STOP WASTE OF WATER.

#### IMPORTANT.

*To the Owner of the Premises:*

To stop waste of water, an inspection is to be made of these premises, and your attention is called to the necessity of having all fixtures in good order, as the rules of the Department provide a penalty of two dollars ($2) for each leaky fixture. The fixtures which are ordinarily found out of order are tanks of toilets, faucets, and ball-cocks controlling overflow of tanks.

You are hereby notified to have all leaky fixtures repaired immediately.

The use of hose, either inside or outside of buildings, is prohibited.

It is hoped that you will do everything in your power to stop all unnecessary use of water so that we may avert as much as possible a situation which would be most serious.

HENRY S. THOMPSON,
*Commissioner.*

One hundred and fifty thousand copies of the above were delivered between June 6 and June 16, 1911, as follows:

1st. One hundred and forty-five thousand copies were delivered on the premises, without folding.

2d. In order to reduce waste in large buildings of various kinds, where the consumption of metered water was very great, and where the department did not intend to make an actual inspection, 4 855 notices were placed in envelopes and addressed to the owner, manager, superintendent, engineer, or janitor of large office buildings, apartment houses, department stores, steam plants, and delivered to the individual in charge.

3d. Where the premises to be notified were outside of the delivery limits of the private concern that was doing this work, notices were mailed, the total number of notices delivered in such manner being 145.

The following table shows the weekly consumption in June in Manhattan and The Bronx and in Brooklyn. As house-to-house inspection did not commence until the middle of June, and less than ten per cent. of all premises were covered in that month, the reduction in consumption noted must have been mainly due to the printed notices:

### DAILY CONSUMPTION DURING JUNE, 1911, BOROUGHS OF MANHATTAN AND THE BRONX AND BROOKLYN.

| | Million Gallons. | |
|---|---|---|
| Week Ending | Manhattan and Bronx. | Brooklyn. |
| June 3 | 283 | 139 |
| June 10 | 292 | 137 |
| June 17 | 279 | 135 |
| June 24 | 289 | 139 |
| July 1 | 282 | 142 |
| Average | 286 | 139 |
| The corresponding figures for June, 1910, were | 329 | 139 |

There was an evident reduction in consumption following the receipt of the notices, and this reduction increased during the month of July, the total reduction being estimated at about 25 m.g.d., or nearly nine per cent. of the supply in Manhattan and

The Bronx. Assuming that the reduction in waste would gradually lessen and entirely disappear in two years,* the total amount of water saved would be over 9 000 million gallons. As the cost of printing and distributing the notices was $1 388, the resultant cost was $0.15 per million gallons saved, or about one quarter of one per cent. of the average cost of water distributed in New York City.

## INSPECTION OF BUILDINGS.

For the house-to-house inspection work a corps of about one hundred and fifty men was employed, there being on an average one clerk at $900 per annum for every four inspectors at $1 100 per annum. The inspectors worked in squads of from fifteen to twenty, in charge of two regular department inspectors. Every building was thoroughly examined, an average day's work of eight hours covering ten buildings.

After the inspection of the premises a notice was mailed by the department, addressed to "The owner or occupant of the premises," calling attention to the leaks found, and notifying the owner to make the necessary repairs to the leaky fixtures, the said form of address being approved by the corporation counsel as a legal notification. Three days were allowed from the date the notice was mailed before a reinspection was made, and if it was found that more than 50 per cent. of the leaky fixtures which had been discovered upon the first inspection had not been repaired, a fine of $2.00 was imposed. After an interval of about a week the premises were again inspected, and if the leaks had not been repaired an additional fine of $2.00 was imposed and this procedure was followed until fines, in some cases, had been imposed as many as seven times on the same premises. Where it was found, after several inspections, that the owner did not occupy the premises in question, his name and address was obtained and an individual notice sent to him, stating that if the leaks on the premises were not repaired, the water would be shut off after three days from the date of notice. In no case was this extreme penalty resorted to;

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*This period of time is used simply as a basis of computation, the exact time required for the leakage to return to the amount existing prior to commencing water-waste work being unknown. It is estimated that at the present time, which is just two years after the house-to-house inspection, the reduction in consumption is about fifty per cent. of that shown immediately after the active campaign was stopped.

although in one case the department men had commenced to dig up the street in front of the premises to shut off the water, when the owner appeared and made immediate arrangements for repairing the leaks on the premises, after paying $9.00 for the work done by the department force in making preparations to shut off the water. The fines imposed became, under the laws of New York, a lien on the property, and therefore readily collectible. Fines were rebated when a satisfactory reason was given, showing inability to comply with the department order within the time allowed.

House-to-house inspection was carried on actively during July, August, and September, and then, owing to the crisis having passed, the force was materially reduced and finally disbanded at the end of the year.

The premises inspected were grouped in districts covering about one hundred city blocks, although the size of the districts varied materially. Pitometer gagings were made immediately before the inspection was commenced in each district, and immediately after the final inspection was completed.

These gagings indicated, as shown by Table 1, that the inspectors saved a maximum of 20 per cent. and a minimum of 2 per cent., with an average of 12.2 per cent., out of a total measured consumption of 175 m.g.d., which is 60 per cent., of the total consumption. The extent of the leakage found, even after the reduction due to the printed notices, is shown by Table 2, from which it will be seen that the number of leaky fixtures averages nearly three to each building. The estimated net cost of this inspection and pitometer work was about $60 000, after the fines were deducted, and even assuming that the leaks then stopped would gradually develop again so that the full amount of leakage reappeared in two years' time, the cost per million gallons would be about $7.70. Assuming an average of one hundred inspectors employed, the amount saved per inspector was 0.21 of a million gallons per day; but if the work had been spread over a longer time, the average per inspector would have been higher, as the cumulative effect of the longer period of work would be shown to the inspector's credit, while the cost would have remained about the same per million gallons.

## TABLE 1.

### SAVING OF WATER SECURED BY HOUSE-TO-HOUSE INSPECTION IN MANHATTAN, AS INDICATED BY PITOMETER GAGINGS OF CONSUMPTION.

| District. | Character. | Daily Consumption before Inspection. Gallons. | Daily Consumption after Inspection. Gallons. | Daily Saving. Gallons. | Saving. Per Cent. |
|---|---|---|---|---|---|
| 1 | Tenement | 8 284 000 | 6 600 000 | 1 684 000 | 20 |
| 2 | Dense East Side tenements | 11 444 000 | 10 613 000 | 831 000 | 7 |
| 3 | Low-class tenements and apartments | 14 823 000 | 12 710 000 | 2 113 000 | 14 |
| 4 | High-class resident district | 12 737 000 | 11 410 000 | 1 337 000 | 10 |
| 5 | Dense East Side tenements | 10 301 000 | 8 680 000 | 1 621 000 | 16 |
| 6, 8 | Tenements and apartments | 14 685 000 | 14 057 000 | 628 000 | 4 |
| 7 | Medium-class apartments | 13 378 000 | 10 894 000 | 2 484 000 | 18 |
| 9, 12 | Medium-class apartments | 13 660 000 | 12 400 000 | 1 200 000 | 9 |
| 10 | High-class apartments | 5 655 000 | 4 664 000 | 991 000 | 17 |
| 13, 14 | High-class apartments | 22 181 000 | 21 690 000 | 491 000 | 2 |
| 15 | Hotel and theater district | 29 482 000 | 23 559 000 | 5 923 000 | 20 |
| 17 | Tenements and apartments | 7 360 000 | 6 234 000 | 1 126 000 | 15 |
| 18 | Business and warehouse district | 10 790 000 | 9 944 000 | 846 000 | 7 |
| Total |  | 174 780 000 | 153 505 000 | 21 275 000 | 12.2 aver. |

$$\text{Saving } \frac{21\,275\,000}{174\,780\,000} = 12.2 \text{ per cent.}$$

|  |  |
|---|---|
| Cost of pitometer gagings | $22 950.00 |
| Cost of inspectors, clerks, etc. | 58 150.00 |
| Total cost | $81 100.00 |

## TABLE 2.

### MANHATTAN—NUMBER OF MEN EMPLOYED, PREMISES EXAMINED, AND LEAKY FIXTURES FOUND DURING HOUSE-TO-HOUSE INSPECTION, JUNE TO DECEMBER, 1911.

| Months. | Number of Inspectors, Average per Day. | Number of Clerks for Office Work, Average per Day. | Number of Premises Inspected. | Number of Leaks Found. | Per Cent. Premises having Leaky Fixtures. | Number of Premises Re-examined. | Number of Fines Imposed for Failure to Repair Fixtures. | Amount of Fines Imposed. |
|---|---|---|---|---|---|---|---|---|
| 1911. | | | | | | | | |
| June | 87 | 13 | 12 834 | 47 370 | 75 | 2 716 | 303 | $606.00 |
| July | 105 | 25 | 18 644 | 56 107 | 69 | 21 405 | 4 496 | 8 992.00 |
| August | 114 | 21 | 23 893 | 48 419 | 60 | 17 753 | 2 175 | 4 358.00 |
| September | 77 | 21 | 10 852 | 33 100 | 70 | 17 366 | 2 510 | 5 020.00 |
| October | 35 | 24 | 4 109 | 7 058 | 48 | 8 803 | 1 823 | 3 646.00 |
| November | 18 | 13 | 1 621 | 3 413 | 47 | 5 215 | 299 | 598.00 |
| December | 7 | 4 | 418 | 1 768 | 56 | 2 233 | 245 | 490.00 |
| Total | | | 72 371 | 197 235 | | 75 491 | 11 855 | $23 710.00* |

* A small percentage of these fines were rebated.

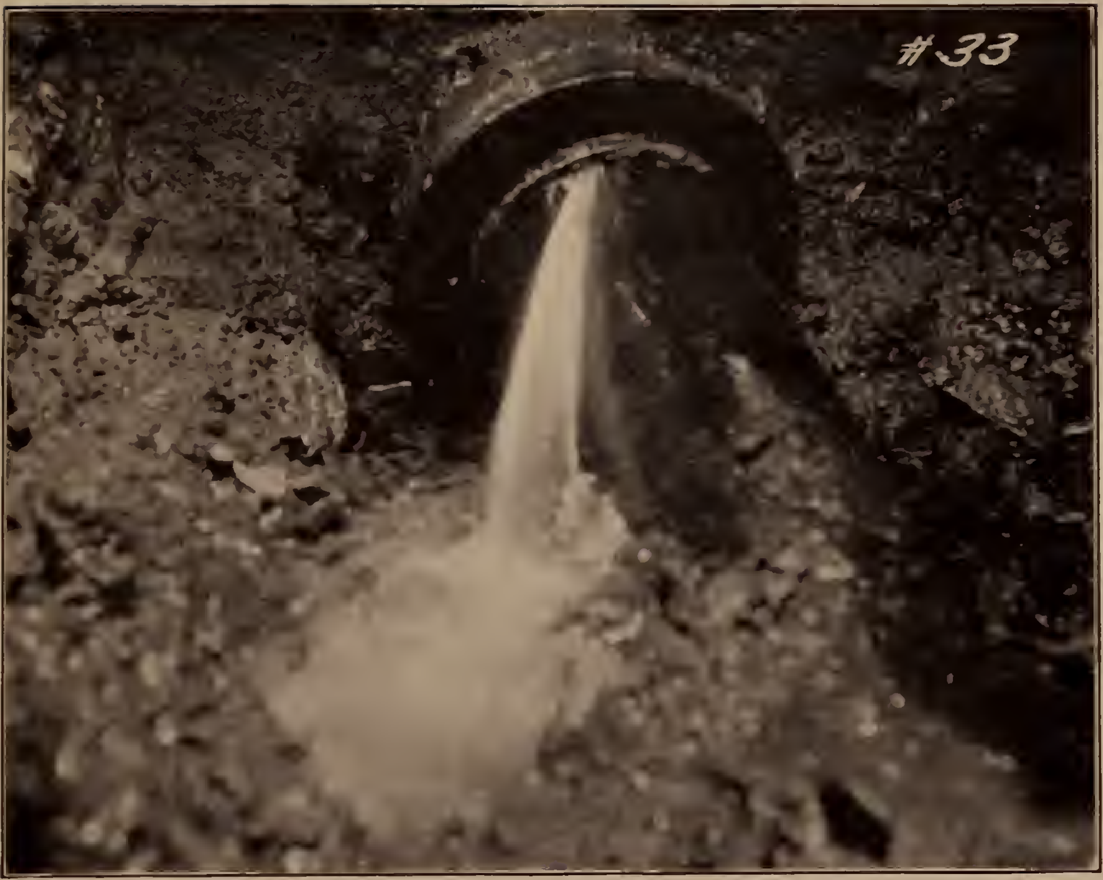

Fig. 1.
Manhattan.
Partially Blown Joint. Leakage 29 000 Gallons per Day.

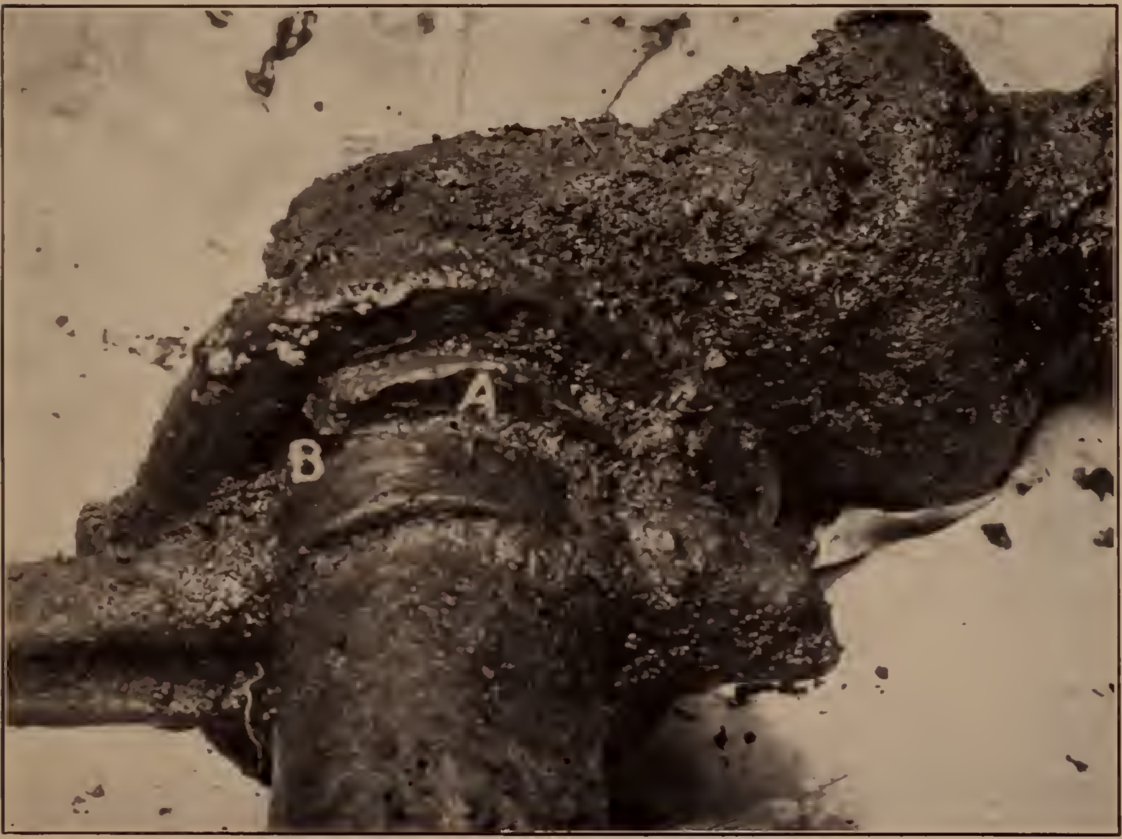

Fig. 2.
Brooklyn.
A Blown Joint on 4-in. Hydrant Branch.
Leakage 300 000 Gallons per Day.

## LEAKAGE IN STREET MAINS AND SERVICES.

To stop waste from leaks in mains outside of buildings, surveys were made with the pitometer, the force employed consisting generally of an engineer in charge, two assistants, and six skilled and unskilled laborers. This work, especially that along the waterfront, was commenced in September, 1910, and carried on almost continuously until December, 1912, the only interruption being when the entire force was used in connection with pitometer gagings of districts covered by house-to-house inspection in the summer of 1911. The leaks discovered were generally from blown joints, broken pipes, and broken or split house services. The character of leaks is shown on Plate XXXI. The total amount of leakage checked by this work amounted to 16 672 000 gal. daily. In connection with the waterfront work there have been over 16 miles of river front examined, containing about 84 miles of mains, with a measured flow into districts of about 40 m.g.d., and leaks were stopped amounting to 10 m.g.d., of which 5.7 million gal. were found in submerged pipe lines.

The cost of this work was $19 000, and if it be assumed that, on an average, the leaks stopped would have been discovered by the regular maintenance force in ten years, the cost of saving this water would be about $0.50 per million gallons. This cost is based upon a sinking fund of 8.7 per cent. annually, and interest at the rate of 4.3 per cent. The leaks on the submerged lines were very large in proportion to the amount of time spent in locating and stopping the same, and therefore in estimating the cost per million gallons for saving the water, it would be reasonable to omit such large leaks. Assuming that the money spent represented the cost of stopping leaks amounting to 4.3 million gallons daily, the cost would be about $1.30 per million gallons.

Table 3 shows the results accomplished in the way of reducing leakage by appeals through the press, printed notices to stop leaks and unnecessary use of water, house-to-house inspection, and stopping leaks from mains and service pipes. In this table the amount credited to each cause is necessarily approximate, with the exception of the leaks from mains and defective services, but the table, nevertheless, gives some adequate idea of the relative

## TABLE 3.

### Reduction in Consumption — Manhattan and The Bronx — 1911.

(Million gallons daily.)

| Consumption. | | | Estimated Consumption assuming Increase 3%, Equivalent to Rate of Increase in Population, 1911. | Estimated Reduction in Consumption. | | | | Total. |
|---|---|---|---|---|---|---|---|---|
| Month. | 1910. | 1911. | | Press Publicity. | Printed Notices. | House-to-House Inspection. | By Stopping Underground Leakage. | |
| January | 335 | 334 | 345 | 0 | — | 0 | 4 | 11 |
| February | 336 | 331 | 346 | 0 | — | 0 | 4 | 15 |
| March | 327 | 327 | 337 | 4 | — | 0 | 6 | 10 |
| April | 326 | 320 | 336 | 10 | — | 0 | 6 | 16 |
| May | 326 | 310 | 336 | 18 | — | 0 | 8 | 26 |
| June | 329 | 286 | 339 | 20 | 21 | 3 | 9 | 53 |
| July | 342 | 287 | 352 | 20 | 27 | 9 | 9 | 65 |
| August | 336 | 275 | 346 | 20 | 26 | 16 | 9 | 71 |
| September | 335 | 277 | 345 | 18 | 22 | 18 | 10 | 68 |
| October | 332 | 278 | 342 | 13 | 20 | 20 | 11 | 64 |
| November | 321 | 271 | 331 | 11 | 17 | 21 | 11 | 60 |
| December | 333 | 283 | 343 | 11 | 17 | 21 | 11 | 60 |

effectiveness of the means employed to reduce waste and unnecessary use of water.

### METERED CONSUMPTION.

The metered consumption, which amounts to about 30 per cent. of the total for Manhattan and The Bronx, or 90 m.g.d., has remained practically constant during the water-waste work, the increase being only that due to normal growth. The reduction has, therefore, been confined to the unmetered consumption, and represents, as a maximum, a reduction of thirty per cent. of said consumption. The per capita consumption in Manhattan and The Bronx, before and after the water-waste work, was as follows:

| Time. | Average Daily Consumption, Million Gallons. | | Average Daily Consumption, Gallons per Capita. | |
|---|---|---|---|---|
| | Total. | Metered. | Total. | Excluding Metered Consumption. |
| January—December, 1910 | 331 | 84 | 120 | 90 |
| January—June, 1911 | 318 | 89 | 112 | 81 |
| July —December, 1911 | 279 | 89 | 98 | 67 |
| January—December, 1912 | 303 | 90 | 104 | 73 |
| January—June, 1913 | 304 | 90 | 102 | 72 |

In New York all water used for business purposes is metered, and the metered services in 1912 in Manhattan and The Bronx numbered 61 500 out of an estimated total of 92 300 metered services in the five boroughs.

It will be seen that, excluding metered consumption, the per capita consumption is low for a large city, but still materially above what is probably necessary for domestic consumption, indicating that the amount of leakage still remaining is large in total quantity although probably difficult and comparatively expensive to eliminate.

### PER CAPITA CONSUMPTION.

The per capita consumption for the last twenty years is shown on Table 4.

From this table it will be seen that the drop in per capita consumption amounted to 30 per cent., i. e., from 134 gal. to 102 gal. This reduction commenced in about 1906, but the cause is not clear prior to the water-waste campaign in 1911. It was probably due, in a great measure, to business depression, New York City, as the financial center and the largest manufacturing city in the United States, very promptly feeling any dullness in trade and resulting reduction in manufacturing.

## WATER-WASTE WORK IN THE FUTURE.

With the excellent and exceptionally low-cost results obtained, the continuance of the waste prevention work would be expected, but owing to the character of the Croton system, it was found to be

TABLE 4.

Per Capita Consumption, 1892–1913, Manhattan and The Bronx, and Brooklyn.

(Gallons daily.)

| Year. | Manhattan and The Bronx. | Brooklyn. |
|---|---|---|
| 1892 | 91 | 74 |
| 1893 | 96 | 79 |
| 1894 | 99 | 72 |
| 1895 | 100 | 75 |
| 1896 | 109 | 85 |
| 1897 | 115 | 88 |
| 1898 | 117 | 88 |
| 1899 | 123 | 88 |
| 1900 | 130 | 88 |
| 1901 | 129 | 86 |
| 1902 | 129 | 86 |
| 1903 | 128 | 85 |
| 1904 | 132 | 90 |
| 1905 | 134 | 91 |
| 1906 | 133 | 96 |
| 1907 | 131 | 101 |
| 1908 | 126 | 100 |
| 1909 | 122 | 95 |
| 1910 | 120 | 97 |
| 1911 | 105 | 92 |
| 1912 | 104 | 91 |
| 1913 * | 102 | 78 |

* First 6 months.

TABLE 5.

BOROUGHS OF MANHATTAN AND THE BRONX, AVERAGE DAILY CONSUMPTION, 1903 TO MARCH, 1913, INCLUSIVE.

(Million gallons.)

| Month. | 1903. | 1904. | 1905. | 1906. | 1907. | 1908. | 1909. | 1910. | 1911. | 1912. | 1913. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| January | 294 | 300 | 314 | 320 | 340 | 325 | 316 | 335 | 334 | 302 | 292 |
| February | 292 | 310 | 320 | 323 | 353 | 340 | 316 | 336 | 331 | 310 | 306 |
| March | 290 | 299 | 319 | 320 | 344 | 329 | 317 | 327 | 327 | 299 | 301 |
| April | 284 | 294 | 315 | 318 | 329 | 325 | 316 | 326 | 320 | 297 | 304 |
| May | 285 | 296 | 313 | 317 | 323 | 322 | 321 | 326 | 310 | 299 | 307 |
| June | 283 | 307 | 315 | 328 | 328 | 340 | 330 | 329 | 286 | 308 | 314 |
| July | 292 | 300 | 323 | 331 | 334 | 342 | 330 | 342 | 287 | 309 | ... |
| August | 287 | 301 | 318 | 316 | 330 | 330 | 329 | 336 | 275 | 305 | ... |
| September | 291 | 307 | 318 | 332 | 323 | 329 | 335 | 335 | 277 | 309 | ... |
| October | 285 | 305 | 321 | 330 | 322 | 321 | 334 | 332 | 278 | 300 | ... |
| November | 284 | 302 | 322 | 326 | 314 | 313 | 322 | 321 | 271 | 297 | ... |
| December | 290 | 311 | 323 | 337 | 316 | 309 | 314 | 333 | 283 | 297 | ... |
| Average | 287 | 303 | 318 | 325 | 330 | 327 | 325 | 331 | 298 | 303 | 304 |

uneconomical to pursue waste prevention work by house-to-house inspection after the sufficiency of the supply was demonstrated beyond reasonable question.

With a gravity supply, which is the condition in Manhattan and The Bronx for about 75 per cent. of the consumption, and with ample aqueduct and reservoir capacity, there is practically no difference in cost when very little water is being drawn and when a full supply is being drawn from the watersheds. The same force has to be employed to care for the watershed, reservoirs, aqueduct line, and distribution system, so that the operation and maintenance cost is not affected by reduction in water waste. The trunk main capacity is, however, affected by the rate of draft, as said mains, in a large, well-designed system, are normally proportioned to the needs for domestic consumption, with some margin for fire purposes. For about every 20 m.g.d. added to the consumption, a 48-in. main has to be laid; so that for each 20 m.g.d. saved, the laying of a 48-in. main can be eliminated. By taking the average length of trunk main required to deliver water from the end of the aqueduct to the center of distribution, and determining the cost of such a main, the monetary value of water saved can be arrived at, assuming there is no reason to save water to prevent extensions to the supply system, which was the case in Manhattan and The Bronx in 1912. Thus, from the terminal of the aqueduct at 135th Street gate house, Manhattan, to the center of distribution, is estimated at 25 000 ft. The cost of laying a 48-in. main in Manhattan streets is estimated at $18.00 per ft., making the cost of such main $450 000. Assuming the capacity of the 48-in. main to be 20 m.g.d., the cost per million gallons capacity would be $22 500. Assuming interest, sinking fund, and maintenance at 5½ per cent., the cost would be $3.39 per million gallons. As the lateral distributors in the distribution system are of a capacity based almost entirely on fire service requirements, there would be no additional saving for such parts of the system, even if the consumption were to be reduced, say 20 per cent.

For the pumped supply, the cost of maintenance and operation, including sinking fund on equipment, is equivalent to about $10.00 per million gallons.

From the above it is evident that for the present there is no financial return from reducing water waste where the cost of such saving exceeds $10.00 per million gallons in districts where the water is pumped and $3.39 per million gallons in districts where the water is delivered by gravity.

When the Catskill water supply is introduced and has been utilized to such an extent that pumping from the Brooklyn system will have to be resorted to if waste of water is not curtailed, a very different financial problem will be presented, and discussion of this problem at the present time is inopportune.

## CONTROL OF LEAKAGE FROM MAINS AND SERVICES.

While financially the house-to-house inspection part of the water-waste prevention work was uneconomical after the fall of 1911, the measurement of flow in mains to detect underground leakage was continued, the force, however, being assigned at times to other work. This work resulted in the discovery and repair, during 1912, of about 33 leaks, divided as follows:

| | |
|---|---|
| Broken mains.......... | 5 |
| Joints.................. | 19 |
| Defective services....... | 9 |

These leaks amounted to 3.8 m.g.d., while the total cost was about $16 000. Assuming that, on an average, these leaks would have been discovered by the regular maintenance force in ten years, the cost of saving the water would be about $1.50 per million gallons. This cost is based on a sinking fund of 8.7 per cent. annually and interest at 4.3 per cent.

The conditions in Manhattan and The Bronx are unusually favorable to the development and continuance of leaks from mains and services outside of buildings, without any indication on the surface. Owing to the rock floor being near the surface, much rock is removed in grading streets and excavating for buildings, the same being used to bring to grade streets crossing hollows. Also, in rock underlaid streets, the water main is usually laid in the sewer trench and the filling offers comparatively free passageway for the leaking waters to reach the sewer. Under the above conditions, leaks amounting to several hundred thousand gallons daily might continue for years without discovery from the appearance of the surface, and leaks of 100 000 gallons daily have been found only after pitometer measurements have shown unreasonably high flows.

To simplify the location of these leaks and to reduce the cost of such location, the department has recently used a "pulsograph," invented by Mr. N. Akimoff, of Philadelphia, which is shown in Plate XXXII. This instrument is based upon the water hammer experiments made in Russia in 1897–98 and reported in paper by N. Jonkowsky before the Russian Technical Society, April 29, 1898. It consists essentially of a large sensitive pressure recorder having a rapid motion, a tuning fork vibrating at a rate of 200 per second, and a quick-operating valve which is on a blow-off or by-pass pipe.

The instrument is set up by screwing it to a hydrant nozzle, the hydrant being chosen so that there will be a straight run of several hundred feet before an open four-way branch is encountered. By closing valves on intermediate branches, the effect of a long isolated line can be obtained. In operation, the valve on the main below the hydrant is closed, and water allowed to flow from the hydrant through the by-pass on the instrument. By quickly closing the by-pass valve, a water hammer of about fifteen pounds is created and recorded on the pressure gage. This pressure is maintained until the water-hammer pressure has reached the open branch at the end of the pipe line that is being tested and the drop in pressure has traveled back to the hydrant, the tuning fork vibrations showing the time for this double travel. By dividing twice the distance along the main to the open branch by the time, the rate of travel for the particular pipe is determined. This has been found to be approximately 4 200 ft. per second for 6-in. pipe and decreasing to about 3 600 ft. for 12-in. pipe. If there is any leak in the main, or in a service near the main, the water-hammer pressure is materially reduced by said leak and the chart shows separately the reduction due both to the leak and the open branch. The distance to the leak can then be determined by the time shown on the chart for the water-hammer pressure to travel to the leak and return to the pulsograph, this being multiplied by the determined rate of travel of the hammer pressure along the pipe, and divided

Plate XXXII.
N. E. W. W. ASSOCIATION.
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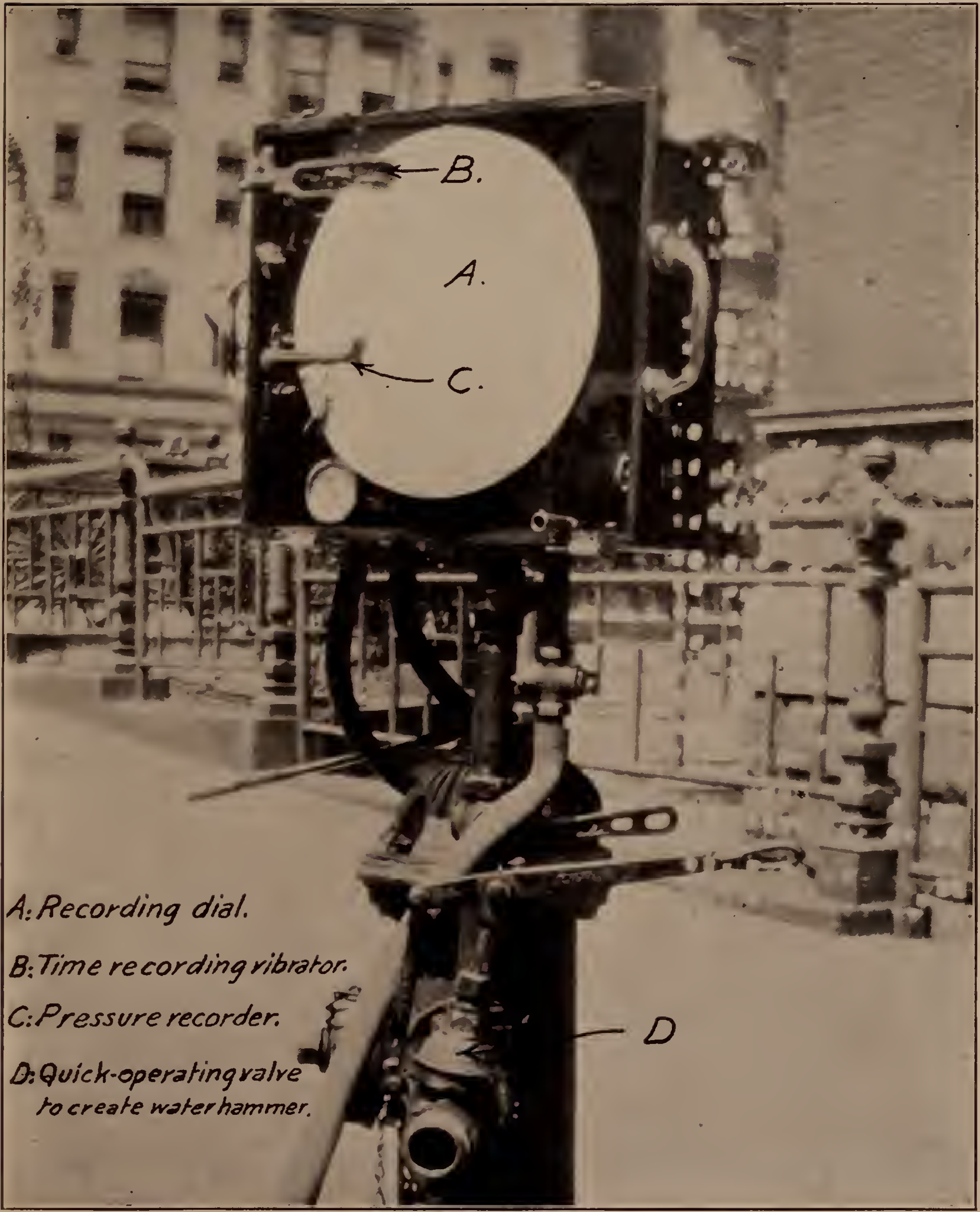
BRUSH ON
WATER WASTE PREVENTION, N. Y.


B.
A.
C.
D
A: Recording dial.
B: Time recording vibrator.
C: Pressure recorder.
D: Quick-operating valve to create water hammer.

Pulsograph in Place on Hydrant.

by two. Several leaks have been located within limits of less than twenty feet by the use of this instrument, and the results from its further use should be interesting, as a decided saving in cost of locating leaks is anticipated.

## TEMPORARY SUPPLY FROM TEN MILE RIVER.

Mention has been made of the recommendation to develop an additional temporary source of supply to meet the threatened danger of water shortage in the Croton Valley. The source selected was the Ten Mile River, a branch of the Housatonic. Surveys were made, and plans, specifications, and contract prepared for the utilization of this supply, at an estimated cost for construction of about $1 200 000, and for operation and maintenance, $183 000 annually. By October, 1911, the heavy rains and resultant run-off, together with the reduced consumption, had relieved the situation sufficiently to make it practicable to stop further work on this project, and no money was actually expended for an additional supply other than in connection with the surveys, preparation of plans, etc.

## METHOD OF DETERMINING MINIMUM STORAGE REQUIRED IN CROTON VALLEY.

An interesting phase of the determination of the need for an additional supply was the fixing of the reasonable safe limit of depletion of storage on January 1 of any year. The Rippl, or mass curve method, is usually adopted in determining the safe maximum draft from any watershed. The run-off from the watershed is plotted for the entire period covered by the records, and a line is drawn representing the maximum draft on the assumption that all water stored in reservoirs would be used during the drought period, if such period were to recur. On this assumption it would be necessary that the run-off become equal to or greater than the draft on the day following the withdrawal of the last of the stored water from the reservoirs, and that the run-off would be sufficient thereafter to eventually refill the reservoirs.

While, theoretically, an engineer might assume such a rate of draft, the operating engineer responsible to nearly three million people for maintaining a continuous supply from sources dependent entirely, at times, upon stored water, would be foolhardy if he allowed the storage to be depleted to such an extent. The rule adopted for New York was that the storage should not go below an amount which, added to the lowest run-off recorded for a year, would equal the anticipated consumption for such year.

The lowest recorded run-off of the Croton watershed for a calendar year was 207 m.g.d. With the consumption reduced to 275 m.g.d., the deficiency was 68 m.g.d., or 24 820 million gallons in one year. As further reduction could at that time have been made in the consumption, if necessary, the figure of 20 000 million gallons was adopted for New York conditions in 1911.

Fig. 1 shows the mass curve of flow of the Croton River during

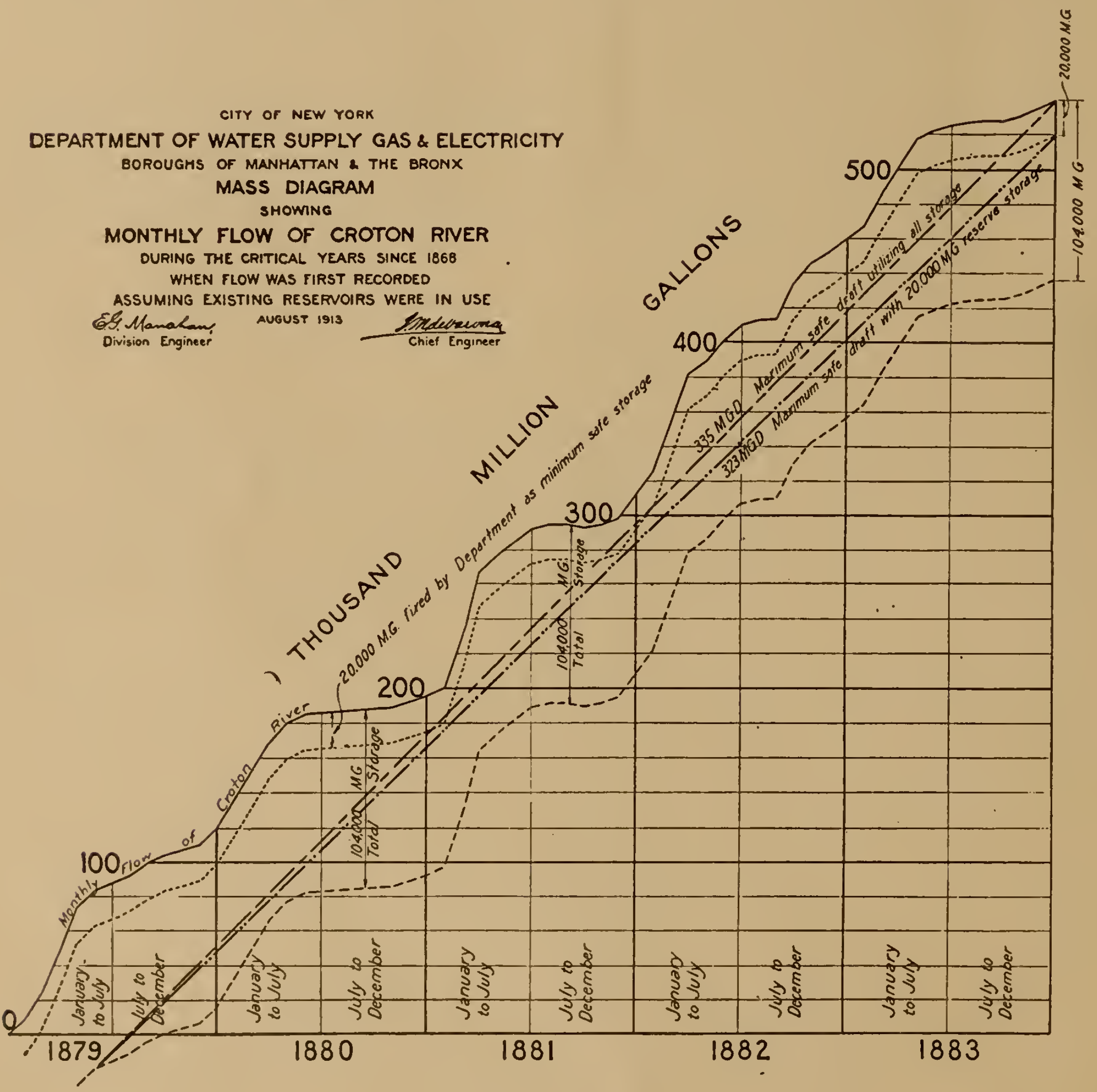


Fig. 1.

the low run-off years, and the two lines of maximum draft, one without any reserve in reservoirs and one with 20 000 million gallons reserve. The first rate is 335 m.g.d. and the second 323 m.g.d. The second is considered the safe rate of draft for New York in the light of the experience of the past three years.

## Borough of Brooklyn.

While Brooklyn has for many years had little or no margin between the consumption and minimum safe supply from the system, there was no difficulty in meeting all requirements in 1911, when Manhattan and The Bronx were threatened with shortage of water. This was due mainly to a large increase in available supply from improvements in the condition of the wells, which furnish about one half of the supply, and to the reduction in consumption probably caused by general knowledge of the unusually dry season and consequent shortage of water in the Croton watershed and in many communities near New York City. The increase in consumption in the winter and spring of 1912 showed clearly that additional stations to draw from the subsurface waters of Long Island would be required unless the growth in consumption was curtailed; the consumption for the first six months being 149.1 m.g.d. as compared with a safe supply of 150 m.g.d. from the works as then developed.

Owing to the expected completion of the Catskill system in 1916 so that water could be delivered at that time to all boroughs, any new works would have a very short useful life, with consequent high cost per million gallons. On the basis of the cheapest type of station machinery and driven well system and without any allowance for conduit capacity or pumping equipment at the main station at Ridgewood, where all the water from the main watershed is pumped into the distribution reservoirs or mains, the cost delivered into the distribution system is as follows:

| | |
|---|---|
| For water made available in 1913 . . . . . . . . . . . . . | $36 per mil. gal. |
| For water made available in 1914 . . . . . . . . . . . . . | 42 per mil. gal. |
| For water made available in 1915 . . . . . . . . . . . . . | 56 per mil. gal. |

If the supply required were to be reduced so that existing sta-

## TABLE 6.

### Borough of Brooklyn, Average Daily Consumption, 1903 to March, 1913, Inclusive.

(Million gallons.)

| Month. | 1903. | 1904. | 1905. | 1906. | 1907. | 1908. | 1909. | 1910. | 1911. | 1912. | 1913. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| January.... | 107.8 | 116.5 | 123.2 | 121.6 | 134.1 | 141.7 | 133.4 | 142.7 | 151.1 | 156.1 | 122.0 |
| February... | 108.6 | 128.2 | 129.5 | 128.7 | 139.8 | 148.8 | 134.4 | 149.7 | 148.9 | 159.1 | 128.9 |
| March..... | 105.1 | 114.5 | 123.6 | 126.1 | 134.8 | 138.7 | 134.1 | 142.8 | 147.5 | 148.6 | 122.6 |
| April...... | 103.0 | 106.6 | 117.8 | 126.3 | 134.0 | 134.4 | 133.5 | 136.3 | 141.0 | 144.0 | 118.6 |
| May....... | 104.8 | 106.5 | 121.5 | 129.5 | 136.6 | 133.8 | 130.3 | 137.2 | 138.4 | 143.8 | 119.3 |
| June....... | 100.7 | 109.0 | 120.3 | 134.3 | 139.0 | 144.7 | 137.2 | 139.1 | 138.5 | 143.1 | 127.6 |
| July....... | 105.2 | 108.4 | 118.3 | 126.3 | 139.1 | 145.7 | 141.3 | 147.6 | 145.5 | 144.2 | .... |
| August..... | 102.0 | 110.3 | 114.7 | 130.0 | 135.0 | 143.9 | 142.0 | 143.7 | 138.9 | 136.1 | .... |
| September.. | 108.1 | 113.2 | 114.0 | 133.0 | 136.6 | 143.2 | 143.0 | 145.7 | 140.8 | 139.3 | .... |
| October.... | 103.7 | 112.7 | 115.3 | 124.7 | 134.6 | 142.6 | 138.5 | 143.6 | 132.6 | 136.5 | .... |
| November.. | 99.6 | 112.9 | 114.0 | 119.3 | 131.5 | 138.5 | 134.1 | 142.1 | 127.7 | 126.3 | .... |
| December... | 108.5 | 119.5 | 119.1 | 125.5 | 132.8 | 132.0 | 136.2 | 146.7 | 133.2 | 126.7 | .... |
| Average.. | 104.7 | 113.1 | 119.2 | 127.1 | 135.6 | 140.6 | 136.5 | 143.1 | 140.3 | 142.0 | 123.2 |

tions could be shut down, the saving in maintenance and operation was estimated at about $24.00 per million gallons.

On the basis of the results obtained from water-waste prevention work in Manhattan and the Bronx, it was evident that such work in Brooklyn, if carried on along similar lines, would be financially advantageous. Work on detection of waste from leaks in mains and services had already been carried on along the waterfront; and owing to absence of rock and rock-filled streets in Brooklyn, there were practically no large leaks that would not show at the surface, other than along the waterfront. It was proposed, therefore, to limit the work in Brooklyn to the sending out of notices and to house-to-house inspection.

In June and July, 1912, 175 000 copies of the following notices were delivered at a cost of $1 137.50, which, together with the printing cost, made a total of $1 412.50.

IMPORTANT.

*To the Owner of the Premises:*

To stop waste of water, an inspection is to be made of these premises, and your attention is called to the necessity of having all fixtures in good order, as the rules of the department provide a penalty of two dollars ($2) for each leaky fixture. The fixtures which are ordinarily found out of order are tanks and toilets, faucets and ball-cocks controlling overflow of tanks.

You are hereby notified to have all leaky fixtures repaired immediately.

The use of hose, either inside or outside of buildings, is prohibited, unless a permit is obtained from the Department.

☞It is hoped that you will do everything in your power to stop all unnecessary use of water. Every gallon of water that is supplied to the Borough of Brooklyn has to be pumped twice, and some of it three times, so every gallon saved means a saving to the taxpayer.

Use what you need, but do not waste it.

Yours truly,
F. T. Parsons,
*Deputy Commissioner, Borough of Brooklyn.*

The consumption showed a drop of 10 m.g.d., see Table 6, which it was estimated was due to the notice. Assuming, as in

## TABLE 7.

### BROOKLYN,—NUMBER OF MEN EMPLOYED, PREMISES EXAMINED, AND LEAKY FIXTURES FOUND DURING HOUSE-TO-HOUSE INSPECTION, JULY, 1912, TO JUNE, 1913.

| Months. | Number of Inspectors. Average per Day. | Number of Clerks for Office Work. Average per Day. | Number of Premises Inspected. | Number of Leaks Found. | Number of Premises Re-examined. | Number of Fines Imposed for Failure to Repair Fixtures. | Amount of Fines Imposed. |
|---|---|---|---|---|---|---|---|
| 1912. | | | | | | | |
| August 31 | 35 | 9 | 8 764 | 9 333 | 1 022 | 18 | $36.00 |
| September 30 | 35 | 8 | 12 289 | 16 650 | 6 483 | 781 | 1 562.00 |
| October 31 | 35 | 8 | 15 064 | 21 861 | 5 788 | 383 | 766.00 |
| November 30 | 35 | 7 | 13 225 | 14 512 | 7 762 | 585 | 1 170.00 |
| December 31 | 35 | 7 | 11 783 | 17 134 | 8 253 | 442 | 884.00 |
| 1913. | | | | | | | |
| January 31 | 36 | 5 | 6 638 | 11 476 | 6 242 | 761 | 1 522.00 |
| February [illegible] | 36 | 5 | 10 757 | 15 713 | 4 482 | 606 | 1 212.00 |
| March 31 | 36 | 5 | 10 885 | 14 252 | 5 785 | 282 | 564.00 |
| April 30 | 36 | 5 | 14 674 | 14 628 | 4 116 | 643 | 1 286.00 |
| May 31 | 40 | 5 | 18 668 | 17 440 | 5 528 | 944 | 1 888.00 |
| June 30 | .. | . | ..... | ..... | ..... | 169 | 338.00 |
| Total | .. | . | 122 747 | 152 999 | 55 461 | 5 614 | $11 228.00 |

Total cost of work to June 1, 1913, $37 074.68.

334.

## TABLE 8.

### SAVING OF WATER SECURED BY HOUSE-TO-HOUSE INSPECTION IN BROOKLYN, AS INDICATED BY PITOMETER GAGINGS OF CONSUMPTION.

| Districts. | Character. | Daily Consumption before Inspection. Gallons. | Daily Consumption after Inspection. Gallons. | Saving. Gallons. | Saving. Per Cent. |
|---|---|---|---|---|---|
| 1, 2, | Mainly business and manufacturing | 23 884 000 | 21 547 000 | 2 337 000 | 10 |
| 3 (x), | Manufacturing and shipping | 13 000 000 | ......... | 2 200 000 | 17 |
| 4, 5, | Mainly resident, medium-class | 17 908 000 | 14 078 000 | 3 830 000 | 21 |
| 6, 7, | Partly residential and business | 12 713 000 | 10 343 000 | 2 370 000 | 19 |
| 8, | Shipping and low-class tenements | 9 250 000 | 7 750 000 | 1 500 000 | 16 |
| 9, | Shipping and low-class tenements | 6 733 000 | 5 396 000 | 1 337 000 | 19 |
| 10, | Manufacturing and low-class dwellings | 9 783 000 | 6 807 000 | 2 976 000 | 30 |
| 11, | Medium-class residential | 9 610 000 | 7 110 000 | 2 500 000 | 26 |
| 12, 13 (x), | Medium-class residential | 12 261 000 | ......... | 3 065 000 | 25 |
| 17, 23 (x), | High and medium-class residential | 10 049 000 | ......... | 2 010 000 | 20 |
|  | Total | 125 191 000 | ......... | 24 125 000 | 19<br>Average |

$$\text{Saving } \frac{24\ 125\ 000}{125\ 191\ 000} = 19 \text{ per cent.}$$

| | |
|---|---|
| Cost of pitometer gagings | $7 200.00 |
| Cost of inspectors, clerks, etc. | 29 500.00 |
| | $36 700.00 |

x Indicates districts in which the saving has been estimated.

Manhattan and The Bronx, that the effect of said notice was lost in two years, the cost was $0.40 per million gallons saved.

Thirty-five inspectors were placed on the house-to-house inspection work early in August, and eight clerks were required to handle the leaks reported. The detailed results of the work of these inspectors, which was continued up to June, 1913, are given in Tables 7 and 8.

It will be seen that the reduction in consumption amounting to 24 m.g.d. effected by the inspection of buildings was much greater proportionally in Brooklyn than in Manhattan and The Bronx, the minimum reduction being 10 per cent. and the maximum 30 per cent., with an average of 19 per cent. This was probably caused by the lesser effect of the printed notices to repair leaky faucets and the elimination of the question of shortage of water in the Brooklyn campaign. In the Brooklyn work there was also a longer period elapsing between the sending out of the notices and the inspection of buildings. The net cost of this work was $26 000, and assuming, as in Manhattan, that the waste stopped would all reappear in two years' time, the cost of saving the water was $3.00 per million gallons. The amount saved per inspector employed was equal to about three quarters of a million gallons daily, which was over three times the amount per inspector in Manhattan. This was due to the work being carried on with a smaller number of inspectors, and each inspector was therefore credited with a larger saving than in the Manhattan work. If comparison is made between Manhattan and Brooklyn on the basis of inspector days, assuming that the leakage stopped would reappear in two years' time, the result is as follows:

| | |
|---|---|
| Manhattan, | 11 600 inspector days, resulting in saving<br>7 800 m.g., equivalent to<br>670 000 gallons per inspector day. |
| Brooklyn, | 9 400 inspector days, resulting in saving<br>8 800 m.g., equivalent to<br>940 000 gallons per inspector day. |

The financial returns in Brooklyn were excellent, it being practicable, with a reduced consumption, to shut down six pumping stations and to use approximately 6 m.g.d. for the Borough of Queens, eliminating thereby an equivalent amount of water purchased from a private company at a cost of $65 per million gallons. It is estimated that the reduction in maintenance and operating charges due to water-waste work is about $300 000 annually.

While the results of water-waste work have been excellent, from the viewpoint of the department, one must not lose sight of the inconvenience to the consumers from house-to-house inspection and the expense involved in the repairs to defective plumbing. It is not believed that the methods adopted should be used except where very favorable results are to be expected, or else where the need for saving water is urgent. Without universal metering, however, it is necessary to adopt temporary expedients for reducing waste and conserving the water supply resources, and these expedients, as applied in New York City, have certainly been most successful.

The house-to-house inspection work was carried on under the direction of the Bureau of Water Registrar, Mr. Benjamin A. Keiley being water registrar for Manhattan, and Mr. Wm. R. McGuire, water registrar for Brooklyn. The general planning and all water measurement work was under the Bureau of Water Supply, of which Mr. I. M. deVarona is chief engineer, the writer having charge of the maintenance and operation work of said bureau.

## DISCUSSION.

Mr. Edward S. Cole.* Some ten years ago the speaker had the privilege of conducting a similar investigation in New York City, which led to the introduction of the pitometer system described in the paper just read, and it is his conviction that 72 gal. per capita daily is twice as much water as the people of Manhattan and the Bronx actually use. This is based upon the well-known character of New York's population, which is overwhelmingly made up of tenement-house dwellers and small water users.

The meter records of Worcester, Mass., show that 10 or 12 gal. per capita covers the actual use of a great mass of that city's population, comprising low-cost homes of mill operatives, etc., and there are many data to prove the same thing. The actual per capita requirements of Manhattan and The Bronx may be apportioned, according to the speaker's experience, as follows:

---

* New York, N. Y.

| | |
|---|---|
| 50 per cent | 15 gal. daily. |
| 20 per cent | 20 gal. daily. |
| 20 per cent | 40 gal. daily. |
| 10 per cent | 100 gal. daily. |

Or an average of about 30 gal. per capita — less than half the figure given by Mr. Brush in his paper as the domestic consumption of the city. From this it is reasonable to conclude that there is yet much to be done in the way of water-waste restriction in New York. Adding a fair amount for unpreventable waste, it should be possible to reduce the present per capita consumption of 72 gal. daily to 40 gal.

We should not forget that the reduction of a few gallons per capita in a great city like New York represents an enormous volume of water. For example, a saving of 30 gal. per capita for a population of 3 000 000 means 90 000 000 gal. per day, the value of which at such a time as the water shortage of 1912 in New York City is beyond calculation.

It was unfortunate that the pitometer tests of 1902 and 1903 were abruptly ended by a change of administration, for the work was only well begun. It is but reasonable to assume that, had our investigation continued, there would have been no such danger of water famine in 1911 and 1912. That the city narrowly escaped a serious water famine in those years is well understood. The rains came in the nick of time, and it would not be wise for any city to risk so grave a danger by so narrow a margin.

The lesson to be drawn from this experience is clearly that water waste in a great city cannot be stopped in a hurry. It takes time to locate underground leakage and losses, and after a system has been made comparatively tight and efficient, it will take constant supervision to maintain it so. In this country we need a system of district metering and supervision like that in use in London and other English cities. Such service is the more imperative in our larger cities, where the general introduction of meters is delayed.

**Mr. W. C. Hawley.**[*] I have only one point in which I differ from the writer, and that is I cannot agree with him that there is no need for restricting leakage in plumbing. It is certainly not fair that " A," who puts a good class of plumbing into his building and maintains it in good shape, should be obliged to pay rates to help keep up a large plant because " B " does not put in a good class of plumbing and does not maintain it.

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[*] Chief Engineer, Pennsylvania Water Company, Wilkinsburg, Pa.

I have had some experience in this matter of hunting for water waste and stopping leaks, which perhaps may be of interest. In 1896, when I took charge of the plant at Atlantic City, the city was facing a water famine. In the previous August the pressure had been at times below 20 lb. per sq. in. The city was already inaugurating a general metering of all services, but there was not time to secure results in that way. We started at once a house-to-house inspection, and where leakage was found a report was made to the owner, with the threat that unless the leakage was stopped at once the premises would be metered. With the universal fear of a meter in an unmetered town we found that to be one of the most excellent arguments that we could advance: it certainly was better than a fine or threat of prosecution. The result was that in four or five months the consumption had been so reduced that we went through the following summer with an ample supply of water, and eighteen months from the time that we began we had reduced the consumption from an average of 250 to 260 gal. per day per capita to 50 or 60 gal.

At the plant with which I am now connected it became necessary to install a filter plant, and about five years ago we began work on the plant. At that time we were pumping about seven and a half million gallons per day, and there was no reason to anticipate a sudden increase in the demand. We planned therefore for a plant capable of filtering ten million gallons per day, with two extra filter tubs that could be equipped if needed, giving an immediate capacity of 12.5 m.g.d., with ultimate expansion to a capacity of 20 m.g.d. By the time the plant was completed in 1909 we found that we were pumping 10 m.g.d., and during that summer many days we were up to 11 m.g.d. We had no knowledge of where this increase was going. The following January we discovered a leak where a 4-in. cast-iron pipe had snapped square in two in the bed of an old run, and about a million gallons per day was going to waste there. Three months later we found a very bad lead joint where a wrought-iron pipe had been leaded into the bell of a cast-iron pipe under a seventeen-foot fill, and another million gallons a day was going to waste there. I came to the conclusion that we should have some way of finding such leaks, so we invested in a pitometer and detectaphone and began a systematic hunt over our system of some one hundred and fifty miles of pipe. The results have been most satisfactory; we have reduced our pumpage materially.

I have some figures which I think would be of interest. For the year ending April 1, 1913, we pumped a total of four hundred and nine and a quarter million cubic feet in round numbers. Of this we accounted for 54 per cent. in industrial consumption; 23.1 per cent. in domestic consumption; and including sewer flush tanks, the free list to municipal buildings and schools, water used by the company in its own office buildings and for meter testing, for the boilers at the pumping stations, the stoker motors, the water used in washing at the filter plant, and that wasted in cleaning the sedimentation basins, we accounted for a total of 79.8 per cent. of the water pumped. With pump slip estimated at 2 per cent. (which of course is low, but our pumps are Riedler pumps and the amount pumped is checked day by day by Venturi meters), that gives us a total of 81.8 per cent., not making any allowance for water used for street washing, sewer flushing, or street sprinkling. And there is practically no estimating as to any of the quantities. It is interesting to note that the domestic consumption averages 24.3 gal. per person per day; our industrial consumption is unusually large, 56.7 gal. per day, so that our total consumption per capita is 105 gal. per day including the 19.1 gal. not accounted for.

It seems to me that while hunting for leaks is absolutely necessary, the prevention of leaks is equally or even more important. "An ounce of prevention is worth a pound of cure." I have found that at least two of the methods which we have adopted have proved very successful. At Atlantic City the leakage was not to any extent from the mains or from the service lines; the leaks were almost altogether in the plumbing, and the meters induced the owners to make repairs. The pressure was low, about 40 lb. normal pressure. In our plant at the present time, while we have pressures up to 210 lb., a large part of our district is under from 100 to 170 lb. pressure, and a considerable part of our leakage is from the mains and from service lines which are lead pipe, as the soil is destructive of iron pipe. Some years ago we adopted the use of a patented coupling instead of the ordinary wiped joint. We have put in a great many of these couplings and we have not had a single case of leakage from them, except where the pipe has been disturbed. I found that fifteen or sixteen years ago a considerable number of one of the earlier forms of patented couplings were put in in one of the old plants which were purchased by our company, and of those couplings not one has given us trouble in the past eight or ten years except where it has been disturbed by some excavation. I believe that the elimination of the wiped joint has made a very material difference in the amount of leakage; and we are eliminating them just as fast as we can.

For some years past we have been using leadite for joints in our mains, and I believe that we have solved another difficulty. We have not had a leak at any of our leadite joints (except one, and that was not important), and we have not had a joint blow out. We find in addition that it has a very high resistance to the flow of electricity, and our mains are being protected from electrolysis.

I think that these are things that are equally as important as hunting for leaks, and will give results that are well worth all that they cost.

Mr. Brush. From what Mr. Hawley has just said, it seems as if I must have given a somewhat erroneous impression as to the attitude of New York City towards leakage. It is not and was not the idea in the water department of New York City that it is not important or necessary to stop existing leaks either in mains or in plumbing inside the buildings or to prevent leaks occurring in the future. As far as leaks in the mains are concerned, we have a permanent force of about fifteen men which is used for detection of leakage in the mains and services; that is, outside of the buildings.

The point that I intended to make was that with a gravity system of a capacity greater than the demand from a financial viewpoint it does not pay to go after the house leakage in a systematic way when your cost of stopping that leakage is greater than the cost of new trunk mains, which is the only expense involved as long as your supply is greater than the demand. Even the cost for new trunk mains has been eliminated at the present time, due to the unusual large reduction in consumption. In other words, our trunk main capacity is now greater than would be really needed for the city of New York with its present consumption, as far as Manhattan and The Bronx are concerned.

At the present time metering is not a matter which is being actively discussed in New York City, because the authorities are not in favor of it; and it is doubtful whether to-day it is financially advisable. But as far as stopping leaks in the system itself is concerned, that is, in the mains and in the services outside of the houses, we believe that as a matter of efficient administration we ought to take the steps necessary to eliminate such leakage. And our experience has been that that leakage comes in the rock-filled streets.

I had charge of the removal of about thirty miles of mains in the borough of Brooklyn, where we replaced the old mains with new ones. Those mains were laid with lead joints and I think that twenty-five joints in the thirty miles would cover those that leaked. None of the joints leaked so as more than to drip, or at most to run a stream which was less than the size of a pencil. Of course a good many places do not have as good joints as Brooklyn, but the above was the experience with mains laid in Brooklyn back in '58 and '59 and removed in the period beginning with 1902.

As far as stopping leaks in the houses is concerned, we believe that in New York it should only be taken up where the financial returns are at the present time considerably greater than the cost of such work, because it is objected to by the majority of the people and is not necessary on the question of a sufficiency of the supply. We certainly believe thoroughly in going after leaks outside of the buildings, and also in going after leaks in the buildings where it is financially advisable to do so.

As I previously said, metering to-day is not a really practical question for discussion in New York; but the time will come in the not very distant future when the general metering of services will be a very important question and one that will then undoubtedly be taken up actively.

Mr. John C. Whitney. I would like to ask Mr. Brush whether he does not consider it very likely that there would be an increase in the waste of water from leaks where new systems are installed in the large buildings in New York City.

Mr. Brush. We do not anticipate any large increase in the number of leaks from that cause. We do anticipate a considerable increase in the amount of water lost through leakage, and it has been the practice in the borough of Brooklyn since 1905 to reduce that loss by a reduction in pressure during the night hours. That is, we keep the pressure during the evening and midnight and early morning hours down to, and slightly below, the pressure during the day time, by controlling the flow at the reservoir. That can be done in a large city with perfect safety, because the draft for fire purposes is small unless the fire becomes a large one, in which case the gates are open at the second alarm. There has been no difficulty in the last eight years of controlling the system that way.

There will certainly be a material increase in the amount of water lost in New York City with increased pressure, and there will be an increased pressure with the introduction of Catskill water. We have pressures as low as 20 lb. covering large areas, and such a pressure is of course unreasonable. Every city in the United States should have a pressure that will carry water to the upper floor of buildings that can be normally economically constructed in the district in question. In other words, we should supply New York City with pressure that would certainly carry water to the top of a building six to eight stories in height, which is the normal height of buildings erected on New York City land.

The question of stopping the leakage in the buildings in New York City is a different problem from that which the majority of cities have to face, due to the large amount of water that is introduced into New York City whenever any new works are constructed. When we consider that it will be eight or ten years before the question of adequate supply will come up, the problem is presented in a different light from that in which it is usually presented. The amount of money involved in stopping leakage is not one of thousands, but it runs up into hundreds of thousands.

I agree with Mr. Cole that our per capita consumption is far beyond what is necessary, but just how far beyond I am not in a position to state. In the next five years most of us will be in a much better position to settle that question in New York City and other cities than we are to-day, because every year adds to our knowledge of what is the proper per capita consumption. In New York an average consumption of around 30 gal. per person is about what is necessary for the ordinary domestic uses in families living in moderate circumstances. Of course when you get into tenements you come down to a much smaller per capita consumption, and there it might run down as low as 15 or 20 gal.

Mr. Beekman C. Little. Mr. President, I should like to ask Mr. Brush if he included in his house-to-house inspection those houses and buildings that were metered. And if so, I wonder if he made any computation of what percentage of the total leakage was found in the houses and buildings that were metered.

Mr. Brush. We did not include the metered premises except by sending printed notices to such premises. We assumed that there was leakage on metered services, but we concluded that with a greater number of unmetered premises than we could inspect we would confine our attention to them. We did not therefore inspect the metered premises.

Mr. Edward D. Eldredge. Mr. President, I would like to ask Mr. Brush if he would consider it advisable for the purpose of preventing leaks that services laid on private land as well as on the public highway should be under the control or supervision of the water department.

Mr. Brush. My personal opinion is that they should be, and furthermore that they should be installed by the department. We have our inspectors who cover the services up to the building; inside the building the department has nothing to do with the plumbing, but under our laws we are not permitted to install services. We install the taps, as they are put in entirely by the city tappers; but we have no control, other than inspection control, over the services to the building. I think that the city should have better control of the plumbing fixtures in the building. That question covers a big field and better plumbing will only come as the property owners realize that it pays to put in good plumbing rather than to allow speculative builders to put in cheap plumbing because eventually the community has to pay the bill for both defective plumbing and leakage and waste of the water supply.

Mr. John S. Ely (*by letter*).* The present systematic attempt to reduce waste in Philadelphia was begun in April, 1912, by starting a thorough house-to-house inspection for leaking fixtures. Pitometer surveys were begun in August, 1912. The work during the first year was confined almost entirely to West Philadelphia.

For convenience in house-to-house inspection, the city was divided into twelve sections, lettered A, B, C, etc., and the blocks in each section were numbered consecutively. Fifty men were employed, at $2.00 per day, with an experienced district inspector as foreman, who laid out the work for his men each morning, assigning a certain block to each man. These inspectors found a great many leaks, and the results of their inspection began to be apparent immediately in reduced pumpage.

The corps has since been weeded out and reduced to thirty, the pay increased to $2.50 per day, and the men provided with aquaphones and taught how to use them. These aquaphones are invaluable in locating leaks in underground service and yard hydrant pipes. By their use about 1 500 such leaking underground pipes have been found.

The aquaphones are also valuable in expediting the work of inspection, for the inspector, by listening on a single spigot, can tell at once whether any water is running in the house, and if there is none, can proceed to the next house, thus saving the time and the inconvenience to the householder of a complete inspection.

The men wear badges and carry cards for identification, and the following general instructions are issued to them:

1. Inspectors must wear their badges on the outside of their coats in plain sight.
2. They must at all times be polite and courteous in their manner, and must cause householders as little inconvenience as possible.
3. They must ask permission of the householder before entering private rooms or bathrooms, and avoid doing anything which might be misconstrued on the part of the householder.
4. They will not waste time over small and trivial leaks. In leaks smaller than $\frac{1}{4}$-in. stream, it is sufficient to call the tenant's

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* Assistant Engineer in Charge of Water Waste Prevention in Philadelphia.

attention to them, and no written notice to repair need be made out. It is of much more importance to spend the time in finding large leaks.

5. They will in all cases carefully examine the service pipe from the street, using an aquaphone, and in cases where there seems to be a leak in the service, it shall be followed up until located and shall be reported to the foreman at the first opportunity.

6. In cases where leaks are found of ¼-in. stream or more, the regular printed notice to repair will be carefully made out and left with the tenant, the duplicate copy being kept and given later to the foreman.

7. Inspectors will spend only enough time in each house to walk rapidly through and note the condition of plumbing. Five or ten minutes should be sufficient in all cases.

8. In cases where leaks of ¼-in. or more are found in rented houses, the name and address of the owner or agent should be taken and written on the duplicate slip.

9. Inspectors shall keep steadily at work during the whole day and endeavor to find as many *large* leaks as possible. The city pays you for your time and is entitled to it.

10. As inspectors are intrusted with discretionary duties, they will be required to display good judgment on all occasions, and lapses from a high standard of conduct will be dealt with accordingly.

A second inspection of those houses where notice to repair has been left is made about one week later. If the leak is still unrepaired, at the second inspection, a "shut-off" man is sent in a few days, and, finding the leak still not repaired, he shuts off the water at the curb.

Two clerks keep the records of the inspections and lay out the work for the second inspections and "shut-off" men.

The work of this corps is best shown by a summary of the first six months of 1913, as follows:

| | | |
|---|---|---|
| Number of buildings inspected | 113 808 | |
| Number of buildings showing waste | 20 780 | (18 per cent.) |
| Number of buildings repaired | 17 371 | |
| Number of buildings shut off | 2 121 | (Many vacant) |
| Fixtures repaired, toilet flush tanks | 12 432 | |
| Fixtures repaired, spigots | 6 663 | |
| Fixtures repaired, yard hydrants | 1 286 | |
| Fixtures repaired, horse troughs | 36 | |
| Fixtures repaired, service and hydrant pipes | 2 367 | |

| | Cost. | Cost per Building Inspected. |
|---|---|---|
| Labor | $7 908.21 | $0.0695 |
| Material | 100.40 | |
| Transportation | 189.10 | |
| Total | $8 197.71 | $0.072 |

The ordinary flush tank of cheap make is responsible for a very large percentage of the total waste. It is often concealed and a good-sized flow may run constantly with very little sound.

In August, 1912, the bureau purchased six Simplex pitometer sets, including recorders. The recorders are of a recently perfected type, giving a twenty-four-hour record of the velocity of flow in red ink on a circular chart, driven by clockwork. They were first used to check the output from the various pumping stations and filter plants. They are now being used to measure the consumption in various districts of the city, a district being isolated in the usual manner by lines of closed valves and the flow into it measured on one or more large feed mains.

In addition, a number of pitometer rods were purchased for use with a U-tube in making night block surveys. For this purpose the apparatus is set up in a shelter box over a tap in the street main at some convenient point. The adjacent territory is then cut in, a block at a time, by closing the valve at one end and feeding past the pitometer. An observer notes the deflections in the U-tube and the time of each deflection. Thus, the night rate of flow into each block is obtained (the work always being done between 11 P.M. and 5 A.M.). A report of these rates is turned in the following morning and house-to-house inspectors are sent through all the blocks which show a high rate until it is satisfactorily accounted for.

In the six square miles of territory examined in this way, only two leaks have been found in the street mains, these being small joint leaks. In all other cases, the leakage has been accounted for in broken service pipes or house plumbing.

A recent improvement in the method of making these night surveys has been made in the following manner. A short section of 6-in. flange pipe has been mounted on a light covered wagon, the pipe having 3-inch hose connections at either end, and a 1-in.

ferrule or pitometer connection in the center. The U-tube is fastened up on the inside of the wagon cover. The block to be examined is shut off at each end, and fed through a fire hydrant from another hydrant on a live block, the wagon being of course stationed between the two hydrants, thus measuring any leakage there may exist in the block.

This method has the following advantages:

1. It permits quicker work because there are fewer valves to handle. The average number of blocks covered in one night is about 20 with the wagon and 15 by the old method.

2. It is cheaper and does away with the necessity of tapping the main for a pitometer connection.

3. It can much more readily be taken to any part of the city, where surveys are desired.

It has the disadvantages of being less accurate in measuring the amount of leakage, giving rates about 30 per cent. less than the old method, due probably to loss of pressure in passing through the hose. An exact value of the leakage is not, however, necessary in rapid surveys of this character.

These surveys, when followed up by a thorough and efficient corps of house-to-house inspectors, are probably the quickest method of reducing waste in any given territory. It is not necessary for the pitometer corps to stop and examine each house and service individually, but only to find the block night rate. Likewise, it is not necessary for the corps of inspectors to examine those blocks where there has been shown to be no leakage. Each corps, therefore, reduces the work of the other. If at the same time, the district in which the work is being done is isolated and the flow into it being measured by recorders, the results of the work can be readily followed. The effects of this work are soon felt in the neighborhood in which it is being done in increased pressures.

The net result of the work done so far has been to reduce the rate of consumption in West Philadelphia from 145 gal. to 125 gal. per capita per day, or about 14 per cent.

The total pumpage for the whole city in May, June, and July, 1913, averaged 301.638 m.g.d., while for the same three months in 1912 it averaged 315.9 m.g.d., a saving of 4½ per cent., although only about one tenth of the area has yet been covered.

Mr. Clemens Herschel* (*by letter*). Nigh two thousand years ago it was written (" De Arte Poetica," 359): " Indignor, quandoque bonus dormitat Homerus " — I become indignant when the excellent Homer occasionally nods (is careless in his statements).

That represents my feelings exactly, on reading in your paper on Water Waste Prevention Work what you say at the top of p. 420.

> " With a gravity supply . . . and with ample aqueduct and reservoir capacity, there is practically no difference in cost when very little water is being drawn [for use and waste] and when a full supply [and waste] is being drawn from the watersheds — . . . cost is not affected by reduction in water waste."

This is one of those insidious and dangerous half truths, amounting to heresy, that has cost the towns and cities of the United States untold millions of dollars during the past fifty years. For you will readily see — no one quicker than yourself, on having your attention called to it — that such doctrine engenders and fixes on a community and its officials habits of waste; and these in turn make necessary " extending the water works " many years before such costly procedures would otherwise have become necessary. Indeed, I know of a case where " extending the water works " was imminent, while utilizing the waste would have presumably sufficed for that city some forty or fifty years.

Mr. Brush (*by letter*). Mr. Herschel criticises the proposition that, where the water works of a community have a capacity greater than the present needs of the community, there is no difference in cost if the amount of water drawn is in excess of the needs of said community, provided the draft is within the capacity of the works and the operating and maintenance charges are not increased.

This is the condition at the present time in the boroughs of Manhattan and The Bronx; and, as stated in the paper, the " cost," or the annual expenditure for maintenance and operation, is not affected by the amount of water now drawn from the watersheds, as the draft is well within the capacity of all parts of the system. There was no intention on the part of the writer to minimize in any way the importance, as a general proposition, of reducing waste of water. There are periods when, due to a combination of circumstances, the cost of reducing waste is greater than the cost of permitting it to continue, and under such conditions the writer believes that the engineer who recommends postponing water-waste prevention work is performing his duty, but he would be negligent if he failed to give ample notice to the responsible officials when there was necessity for undertaking water-waste prevention work, to avoid extending the water supply system.

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* Civil and Hydraulic Engineer, New York City.

The closing paragraph of the section covering "Water-Waste Work in the Future" shows clearly the writer's belief that, in the future, water-waste prevention work in New York City will again become a most important and vital financial question, and is now important as far as it relates to leakage from mains and services.

# DECARBONATION AS A MEANS OF REMOVING THE CORROSIVE PROPERTIES OF PUBLIC WATER SUPPLIES.*

BY GEORGE C. WHIPPLE, OF HAZEN & WHIPPLE, CONSULTING ENGINEERS, NEW YORK CITY; PROFESSOR OF SANITARY ENGINEERING IN HARVARD UNIVERSITY.

## DISCUSSION (*continued from page 227*).

[*September 11, 1913.*]

MR. L. B. LITCH.† Free $CO_2$ and the corrosion of iron pipes, producing the so-called " red water plague," are closely associated. Filtered waters in general, and particularly those which have been treated with sulphate of alumina or sulphate of iron, have been shown to be more corrosive than unfiltered waters. Extra precautions should be taken to prevent, if possible, this increase in corrosive action.

At the suggestion of Professor Whipple, experiments were conducted at the Steelton filtration plant; and as a result of these experiments new operating and controlling features were added to its regular routine. The Steelton filtration plant is best described in " The Purification of the Water Supply of Steelton," by James H. Fuertes.‡

The raw water supply of Steelton is from the Susquehanna River. Above the filtration plant this river has four tributaries. The north and west branches unite to form the main Susquehanna River at a point 60 miles above Steelton. The Juniata and Conedogwinet Creek flow into the main river at a point 16 miles above Steelton. The north branch drains the hard coal regions of Pennsylvania; the west branch, the sandstone and shale; the Juniata, limestone and red sandstone; and the Conedogwinet Creek, a limestone region. The drainage areas of these different tributaries are semi-mountainous and the streams are, therefore, more or less "flashy." The chemical characteristics of the waters of these different streams, as well as their appearance, differentiate them sharply from one another.

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* This paper was published in JOURNAL N. E. W. W. A., Vol. 27, p. 193.

† Steelton, Pa.

‡ Trans. Am. Soc. C. E., Vol. 66, p. 135.

The temporary hardness of the water from the north branch is very low; the permanent hardness very high. The color of the turbidity is black or grayish-black, but the suspended particles are partially coagulated, although the water is not clear between the flocs. The temporary and permanent hardnesses of the water from the west branch are low, the color of the turbidity is gray, and the suspended matter is so well-coagulated in very small flocs that the water is often clear enough between flocs to be filtered without the use of additional coagulant. The temporary hardness of the Juniata River and the Conedogwinet Creek are very high; the permanent hardnesses very low. The color of the turbidity of the Juniata River is red in its lower and yellow in its upper reaches. The color of the turbidity of the Conedogwinet Creek is yellow. The waters of these two last tributaries are clay bearing and the turbidities are typical of such waters.

The alkalinity of the Susquehanna River water at Steelton varies from 2 to 68 parts per million; the free $CO_2$ from 2 to 8 parts per million.

During ordinary stages of the river, the waters from the different tributaries do not mix in the main river but flow past Steelton in streaks so distinct that the four colors of turbidity may be noticed at one time. At such times there is very little mixing of these different waters. However, when a heavy rainfall occurs on any one drainage area, the whole river at Steelton predicts the character of the stream draining it. When the rainfall is general the characteristics of the individual tributaries appear in the Susquehanna at Steelton in a regular sequence, dependent upon the distance from Steelton to the points where the various branches empty into the main river.

Naturally the river frequently shows the effect of transition from one type of water to another. For example, there is the so-called "switch" water. This is a mixture of yellow or red water with the black water. It appears after the crest of the black water flood has passed. This "switch" water cannot be coagulated by alum alone, despite the fact that the alkalinity ranges from 35 to 45 parts per million. This phenomenon has been observed at other points on the Susquehanna River. Soda ash is not effective to assist coagulation, but lime can be used with satisfactory results, the treated water being well coagulated and clear between the flocs. Frequently there is no reduction in the alkalinity of this water after alum has been added. The raw water after boiling is frequently acid to phenolphthalein.

Because of the varying character of the raw water described above, and also because of a very short reaction period (twenty-eight minutes) previous to passing the water to the roughing filters, it was imperative that the peculiarities of each class of water be studied in order that a satisfactory coagulant might be obtained when chemical treatment was necessary. In order to study the peculiarities of these waters, a 10-meter Kohlrausch bridge and apparatus for measuring the electro-conductivity of the water was added to the laboratory equipment. By means of this apparatus, chemical reactions, which are so slight that they cannot be measured accurately by the titration methods of ordinary chemical analysis, may be accurately recorded. Furthermore, reactions may be studied experimentally and during their whole course without removing any of the solution experimented with, thereby keeping the experimental volumes constant.

In treating the "switch" water with alum, an increase in conductivity is noted. The amount of this increase remains practically constant, thus indicating either that no aluminium hydrate is being formed, or the formation of a soluble salt. When this water was tested for free $CO_2$ after the addition of alum, a slight increase in the amount of $CO_2$ was noted, but only to the extent of about 25 per cent. of the amount called for theoretically by the addition of any given amount of alum. The corrosive action on iron of this treated water is greater than that of the untreated water, but it can be reduced greatly by the addition of lime. Lime, however, is never added in excess; its addition is controlled by the conductivity method mentioned above.

The corrosive effect of $CO_2$ is greater when the alkalinity is low than when it is high. Again, the increase in free $CO_2$ resulting from the addition of lime to a water of low alkalinity tends to arrest, or at least retard, the complete reaction between the alum (aluminium sulphate) and the alkalinity (calcium and magnesium bicarbonates). Under this condition, it has been shown that there is an aluminium compound remaining in solution. This condition should be avoided in plants using alum as a coagulant. It is the practice at Steelton to consider $CO_2$ under the varying conditions of its occurrence, and to apply the proper corrective treatment for it when necessary. As a result of this treatment, the borough prides itself upon the small amount of red water trouble which has occurred.

When applying coagulant, under ordinary conditions, to any one of the typical waters described above, the residual alkalinity is never allowed to go below 10 or 12 parts per million, and when coagulating a raw water which is changing in character rapidly, lime enough to combine with the amount of $CO_2$ equivalent to the amount of alum added is always used, thus insuring the practical completion of the reaction in accordance with chemical theory and preventing the formation of any compound of aluminium other than the hydrate.

More study should be made of the reaction between alum and the water which is treated. Filter plant chemists and superintendents have been too much inclined to place reliance upon the theoretical reaction between alum and alkalinity given in the text-books, as explaining the reaction which takes place in practice, where the theoretical action never takes place because interfering chemicals are never absent. It is the writer's belief that the subject should be approached from the standpoint of physical chemistry, and because the reactions are taking place in extremely dilute solutions, the laws of mass action should be regarded with due consideration.

Mr. Edward D. Eldredge.* I have had an experience in Massachusetts which in some features is unique, and to which Professor Whipple's paper particularly applies. Our supply ranks with one other in having the least color, and in the scale of hardness it ranks zero, — the only one in the state of Massachusetts having that rank. The result is that during certain periods of the year, notably in the spring, there is considerable trouble from red water. The supply is obtained from a woodland pond fed by springs, and having no stream flow in or out. The watershed is entirely wooded with oaks and pines, and the soil is sandy. During the spring, when the level of the pond is rising, there seems to be present a considerable amount of carbonic acid, presumably taken from the decomposing vegetable matter on the surface of the watershed. Some seasons the amount of carbonic acid is greater than others, notably the year 1911, when in April there were three snowstorms which covered the surface like a wet sponge. The absorption of carbonic acid at that time seemed to be greater than in any other period that we have noticed. In 1912 the rainfall was normal and there was not such a noticeable amount. This last spring, 1913, the rainfall was quite excessive in April, and we noticed similar trouble with red water. As a result of Professor Whipple's paper last winter I made some experiments with calcium hydrate. I made a saturated solution of the hydrate and added it in small quantities to a sample of water in which were immersed pieces of iron and steel, to ascertain the action as a result of the addition of the hydrate. The action was very marked; a small quantity of calcium hydrate reduced the oxidation of the metal. It is my purpose, with the authority and advice of the State Board of Health, to adopt some method of introducing calcium hydrate, or some better chemical if possible, with the idea of reducing the red water plague during that particular season when the pond is receiving its new water. I presume the subject must be familiar in other localities where water is very soft.

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* Superintendent Onset Water Company, Onset, Mass.

For service pipes we have found that cement-lined gives the best results, the water having no action on the cement. With galvanized iron we have found a number of cases where the pipes had become so much corroded and filled with tubercles that they had to be removed.

JULIAN S. SIMSOHN, ESQ.* I note in Mr. Whipple's paper that he states carbonic acid gas can be as quickly and efficiently removed by soda ash as by lime. My experience has been that lime is somewhat superior, because the carbonic acid combines with it and can be removed in the filters as insoluble carbonate of lime. Soda ash, on the other hand, combines with carbonic acid to form bicarbonate of soda, a soluble product, which passes through the filters and into the supply. In hot water systems the bicarbonate of soda is decomposed, liberating carbonic acid, which is then at liberty to attack the piping. These thoughts are the result of experiments on both soda ash and lime, and in practice I have found the lime treatment to stand alone in producing a water entirely free from carbonic acid and its corrosive properties.

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* With the Electrolytic Purification Company, Philadelphia, Pa.

MR. R. S. WESTON* (*by letter*). At Reading, Mass., where there is a deferrization plant, the $CO_2$ is removed by the addition of lime, and the writer is informed that no corrosion of the pipes has occurred since lime was used.

In ordinary aëration by spraying downwards from perforated plates or sprinklers, it does not pay to provide for a fall of more than one meter, or 40 in. To obtain a better removal of carbon dioxide without the addition of chemicals, it is essential to expose the water in a thin layer to the action of the air. The action of the air always displaces the carbon dioxide, — at first rapidly, and then slowly, until equilibrium between the carbon dioxide in the atmosphere and that in the water is established. The rough surfaces in a bed of coke, brick, paving blocks, or in superimposed bundles of wooden slats greatly accelerate the washing out of carbon dioxide by the oxygen of the air. Dr. Dunbar, of Hamburg, has shown that if a coke bed, used for iron removal, be operated intermittently, it will absorb oxygen during the periods of rest, which oxygen will replace the carbon dioxide in the water during periods of operation.

At Reading, Mass., an aërator consisting of a bed of broken stone 3 ft. thick increased the oxygen in the water from 1.18 to 5.27 parts, and decreased the carbon dioxide from 20.0 to 7.2 parts per million.

At Rumford Falls, Me., the aërator used to treat the ground-water supply consisted of fifteen trays with perforated bottoms, placed one above another and spaced about 1.5 ft. apart. This apparatus reduced the carbon dioxide from 48 to 5 parts per million. By filling only two of the fifteen trays with broken stone, the carbon dioxide was further reduced to 3 parts per million, thus showing the results of contact.

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* Consulting Sanitary Engineer, Boston, Mass.

At Middleboro the following results were obtained with a well water having a temperature of 11.6 ° cent.:

| | Parts per Million. | |
|---|---|---|
| | Dissolved Oxygen. | Carbon Dioxide. |
| Well water, | 3.3 | 48 |
| Ditto, after dripping 1.5 ft. from a spray nozzle, | . . | 40 |
| Ditto, after trickling over a depth of 4.5 ft. of coke and broken stone at a rate of 75 m.g.a.d., | 10.7 | 5.0 |
| Ditto, after passing through a depth of 3 ft. of coke submerged in water, in a subsiding basin, | 10.3 | 4.5 |

At Cohasset, Mass., the following results were obtained with a well water having a temperature of about 10° cent.:

| | Parts per Million. | |
|---|---|---|
| | Dissolved Oxygen. | Carbon Dioxide. |
| Well water, | 2.4 | 51 |
| Ditto, after falling 3 ft. from the spray nozzle, | 4.5 | 41 |
| Ditto, after passing through a depth of 5 ft. of broken stone, all submerged, the rate of passage being equivalent to 75 m.g.a.d., | 5.75 | 29 |
| Ditto, after falling 3 ft. from a spray nozzle and then trickling over a depth of 5 ft. of broken stone not submerged and operating at a rate of 75 m.g.a.d., | 10.5 | 7.7 |

At Brookline experiments are being conducted to determine the most efficient method of aërating the water, as follows:

System No. 1. Spraying from a nozzle from a height of 1.5 ft.

System No. 2. Spraying from a nozzle and then allowing the water to trickle over a layer of coke 2 ft. in depth at a rate of 75 m.g.a.d.

System No. 3. Like No. 2 but with a layer of coke 5 ft. in depth.

System No. 4. Like No. 2 but with a layer of coke 10 ft. in depth.

The following results are typical. The temperature of the water at the time of the experiments was 15.5° cent.

| | Parts per Million. | |
|---|---|---|
| | Dissolved Oxygen. | Carbon Dioxide. |
| Wells, | 2.02 | 24.8 |
| Effluent, System No. 1, | 8.49 | 8.5 |
| ,, ,, No. 2, | 8.90 | 5.5 |
| ,, ,, No. 3, | 9.55 | 5.2 |
| ,, ,, No. 4, | 9.63 | 4.8 |

The effect of aëration in contact varies with different waters, as well as with the relative temperatures of air and water and the intimacy of the contact between the same.

In order to increase hardness of water, it is often more convenient to spray water over broken limestone or marble than to apply to it the proper amount of calcium hydrate. The writer feels certain that it is always best to decarbonize the water to the practicable limit by aëration before beginning the addition of chemicals to reduce the corrosive effect of the water.

Prof. G. C. Whipple (*by letter*). There is one phase of the decarbonation question that was not mentioned in the original paper, namely, the effect which the addition of lime has upon the bacteria in water. Dr. A. C. Houston, of London, has shown by an interesting series of experiments that when water is treated with an excess of lime, such bacteria as those which cause typhoid fever are speedily destroyed. More recently, Mr. C. P. Hoover, the chemist-in-charge of the water filtration plant at Columbus, Ohio, has performed an even more important series of experiments, which indicate that typhoid fever bacilli die within a few hours in water from which the free carbonic acid has been removed. In other words, his experiments indicate that disinfection is obtained by the use of a smaller amount of lime than Dr. Houston contemplated using. Mr. Hoover's researches are published in the *Engineering Record* of September 6, 1913. This detailed account of the experiments is worthy of careful study. His conclusions were stated as follows:

(1) When enough lime is added to water to absorb the free and half-bound carbonic acid and to precipitate the magnesium content, the bacteria of the colon and typhoid group are killed in forty-eight hours after being so treated, provided the water does not contain large quantities of organic matter.

(2) The germicidal action is effective in from five to twenty-four hours when an excess of 1.2 to 1 gr. per gallon is added beyond that needed to reduce the temporary hardness to the lowest possible figure.

(3) Intestinal organisms will not live in water containing no free or half-bound carbonic acid.

(4) Lime-softened water inoculated with typhoid organisms or with crude sewage soon becomes free from them.

(5) The action is selective in that certain harmless bacteria grow, but the disease-producing germs do not.

It seems to the writer that if Mr. Hoover's experiments can be trusted, and they seem to have been made with the greatest care, we have here a partial explanation of the enhanced safety of water during storage in natural lakes and reservoirs.

It is a fact that has been established during recent years that algæ and other aquatic plants frequently use up all of the free carbonic acid during their growth by the biological process known as photo-synthesis. They will even remove some of the half-bound carbonic acid. It would appear, therefore, that this natural decarbonation of the water tends of itself to destroy such bacteria as the germs of typhoid fever.

Thus we see that natural storage tends to disinfect water even though the storage be short, provided that algæ are growing vigorously in the water. The term " purging," which is sometimes used to describe growths of algæ in ponds, is thus seen to have a meaning that is justified.

The title of Table 10, page 220, is slightly misleading. The figures given in the table do not show directly the reduction of carbonic acid, but rather the amounts of carbonic acid left after the stated periods of exposure.

The writer desires to thank those who have contributed to the discussion, and especially Dr. Thresh for his interesting account of English conditions. Mr. Simsohn states that he prefers lime to soda ash for the purpose of decarbonation, and with this idea the writer is in accord. Mr. Litch, of Steelton, has been carrying on a very valuable series of experiments on coagulation, and it is hoped that some day he will publish these in a more extended form so that the members of this Association may have the benefit of his work.